Exploring Students’ Patterns Of Reasoning

Mojgan Matloob, Sytil Murphy & Dean Zollman
Kansas State University
Cynthia Sunal & Dennis Sunal
University of Alabama

Cheryl Mason
San Diego State University

Supported by National Science Foundation Grant ESI-055494
Introduction - What is Content Question

- A type of assessment
- Open ended question
- Elicit students’ reasoning

Predetermined:
- Cognitive load
- Type of reasoning
- Knowledge types
- Required skills

Newly learnt concept

New Context
Example question in Biology

• You are given four plants with different seed pods and flower colors (yellow and white). You breed the plant with swollen pods and yellow flowers to the plant with pinched pods and yellow flowers. The result is some plants with swollen pods and white flowers and others with swollen pods and yellow flowers. Predict which trait is dominant and recessive?

How to determine the cognitive load and level of abstraction?
Bloom’s revised taxonomy for classifying the components of reasoning

<table>
<thead>
<tr>
<th>Knowledge Dimension</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual knowledge</td>
<td>Knowledge of elements and essential facts</td>
</tr>
<tr>
<td>Conceptual knowledge</td>
<td>Knowledge of classification, principles, theories, and structures, Conceptual schema</td>
</tr>
<tr>
<td>Procedural knowledge</td>
<td>Knowledge of subject-specific skills, algorithms, techniques, methods and procedures</td>
</tr>
</tbody>
</table>

1-Anderson et. al, 2001
Bloom’s revised taxonomy for classifying the components of reasoning, Cont.

<table>
<thead>
<tr>
<th>Table 2- Selection from Cognitive Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Remember</strong></td>
</tr>
<tr>
<td><strong>Understand</strong></td>
</tr>
<tr>
<td><strong>Apply</strong></td>
</tr>
<tr>
<td>Factual</td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td>Conceptual</td>
</tr>
<tr>
<td>Classification</td>
</tr>
<tr>
<td>Procedure</td>
</tr>
<tr>
<td>Compare</td>
</tr>
<tr>
<td>Infer</td>
</tr>
<tr>
<td>Apply</td>
</tr>
</tbody>
</table>

Rubric (In-depth, developed, Naïve)\(^1\) for each component of Bloom’s Taxonomy

4-Wiggins and J. McTighe (1998)
Modification to Lawson’s\textsuperscript{2} definition to make it appropriate for physics contexts

Scientific Concepts

- **Descriptive**
  - Concepts directly observed or sensed e.g. magnets, temperature

- **Hypothetical**
  - Concepts indirectly observed by measurement, or analogical model e.g. magnetic field

- **Theoretical**
  - Concepts that can not be observed and comprehend from logic and theories e.g. photons

2-Lawson et. al (2000)
Type of concept links

- One Concept-Level link
  - Descriptive → Descriptive

- Cross Concept-Level link
  - Hypothetical → Theoretical
  - Hypothetical → Descriptive
  - Theoretical → Descriptive

- Multi Concept-Level links
  - Hypothetical
  - Theoretical

3-Neiswandt & Bellemo 2009
<table>
<thead>
<tr>
<th>Type of Reasoning</th>
<th>Rubric</th>
<th>Concept link</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Yellow is dominant and swollen is dominant”</td>
<td>Naive</td>
<td>T,D</td>
</tr>
<tr>
<td>“I predict that swollen are dominant and white is recessive because you had no pinched pods after the cross and still have yellow flowers”</td>
<td>Factual, Conceptual, (Developed) Others(Naïve)</td>
<td>T-D</td>
</tr>
<tr>
<td>“Both swollen pods and white flowers are dominant. Swollen pods are present in all offspring while pinched are not. White flowers come from the recessive-recessive of the yellow”</td>
<td>Factual, Conceptual, (Developed) Others(Naïve)</td>
<td>T-D</td>
</tr>
<tr>
<td>“When both yellow were breeded white did appear which seems to claim that only when 2 heterozygous plants cross the white recessive gene can appear”</td>
<td>In-depth T-T-T Presence-Dominance Recessive-Recessive-White</td>
<td>T-D</td>
</tr>
</tbody>
</table>
The bar chart represents the frequency of responses in the context of 'Apply' and 'Concept-links'.

For 'Apply', the chart shows:
- Naïve: Approximately 60%
- Developed: Approximately 20%
- In-depth: Approximately 10%

For 'Concept-links', the chart shows:
- T,D-D: Approximately 10%
- T-T-D: Approximately 5%
- T-D: Approximately 60%
- T-T-T: Approximately 30%
Conclusion

✓ We can devise content questions with predetermined level of thought processes

✓ Assessment tool that categorize different levels of thinking

✓ We can find the weaknesses and strengths of students’ reasoning in our classification scheme (concept structure, type of knowledge or cognitive process)

✓ Students’ performance decline when the higher hierarchies of knowledge is required

✓ As the answers display in-depth level of knowledge the conceptual structure is more shown to be multi-level link
Thank you

mojgan@phys.ksu.edu